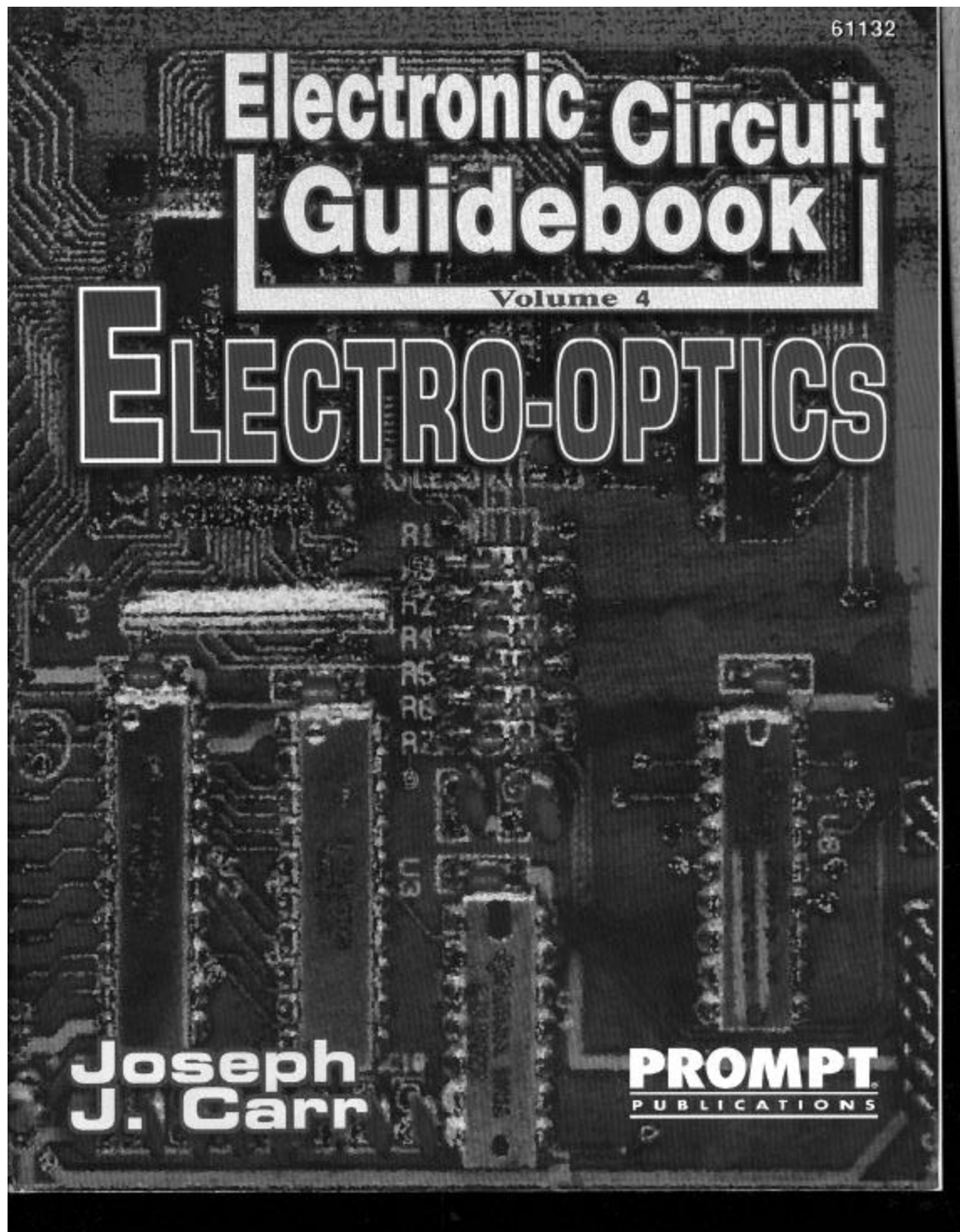




Contents

Chapter 1

Introduction to Light and Electro-Optics	1
A Brief History of Light.....	2
The Early Scientists	2
Early Scientific Philosophies	7
Twentieth Century Developments	9
Waves	12
Frequency and Wavelength.....	12
Electromagnetic Waves.....	14
Wave Propagation	17
The Electromagnetic Spectrum.....	22
Standing Waves	23
Summary	25

Chapter 2

More Light Physics	27
Light Level Measurements	27
Electron Behavior in Electric and Magnetic Fields	30
The "Billiard Ball" Model of Electron Dynamics	31
Electron Motion in Linear Electrostatic Fields.....	31
Example 2-1	35
Solution.....	35
Example 2-2.....	35
Solution.....	36
Why Not a Perfect Vacuum?	36
Motion in an Orthogonal Electric Field	37
Example 2-3.....	38
Solution.....	38
Example 2-4.....	39

Solution.....	39
Relativistic Effects on Electrons	39
Example 2-5.....	40
Solution A	40
Solution B	40
Electron Motion in Magnetic Fields.....	41
Example 2-6.....	43
Solution.....	43
Example 2-7.....	44
Solution.....	44
Electron Motion in Simultaneous E and H Fields.....	44
Motion in Parallel Fields.....	44
Quantum Mechanical Description Of Electrons	46
Example 2-8.....	51
Solution.....	51
Summary	54
References	55

Chapter 3

Mirrors, Prisms and Lenses	57
The Keys to Electro-Optical Instruments	57
Refraction and Total Internal Reflection.....	58
Example 3-1.....	60
Solution.....	60
Example 3-2.....	62
Solution.....	62
Refraction/Reflection from Slabs with Parallel Faces	63
Shimmering, Mirages, and Looming.....	64
Mirrors	66
Ray Tracing and Sign Conventions	67
Planar Mirrors	69
Spherical and Parabolic Concave Mirrors	71
Example 3-3.....	75
Solution.....	75
Example 3-4.....	76
Solution.....	76
Spherical Aberration.....	77
Convex Mirrors	78
Lenses	79
Standard Rays and Labeling for Lenses	81

Example 3-5	85
Solution	85
Example 3-6	86
Solution	86
Lens Defects	87

Chapter 4

Photoemissive Sensors: Phototubes and Photomultiplier Tubes	89
Photomultiplier Tubes	94
Spectral Response of Photoemissive Sensors	98
Phototube and Photomultiplier Tube Applications	100

Chapter 5

Light Sources	105
The Sun, Fire and Flames	106
Incandescent Light Source	106
Glow Lamps	107
Solid-State Light Sources	108
PN Junction Light Radiators	112
LED Construction	117
Mounting LEDs	119
Simple LED Circuits	119
Example 5-1	121
Solution	121
Variable Brightness LED Circuits	121
Example 5-2	123
Example 5-3	124
Example 5-4	125
Driving LEDs from Digital Circuits	126
Example 5-5	127
Solution	128
Example 5-6	130
Polarity Tester	132
Voltage Comparator Output State Indicator	133
Voltage Level Indicators	134
Homemade LED Optocoupler	135
Simple Digital Logic Probe	136



Chapter 6

Photoconductive Cells	139
Spectral Response	141
Sensitivity	143
Relative Sensitivity	144
"Light History" Errors	145
Temperature Coefficient	145
Response Time	146
Photoresistor Circuits	147
Example 6-1	149
Solution	149
Light Meter Circuits	150
Light-Operated Tone Generator	151
Light-Controlled Relays	152
Light-Operated Audio Switch	154
Optical Chopper for Low-Drift Amplifiers	155
References	156

Chapter 7

Photovoltaic Cells	157
Photovoltaic Phenomena	158
Metal-Oxide/Semiconductor Devices	158
Silicon PN Junctions	160
Infrared Photovoltaic Sensors	162
Photovoltaic Cell Characteristics	164
Photovoltaic Cell Applications Circuit	168
Instrumentation/Communications Applications	168
Example 7-1	170
Solution	170
Solar Cell Applications	172

Chapter 8

Photodiodes and Phototransistors	179
Photodiodes	182
PIN Photodiodes	185
Avalanche Photodiodes	186
Phototransistors	187
Application Circuits	193
Selecting a Sensor	196

Chapter 9

Optoisolators, Optocouplers and Optoswitches	199
Optoisolators and Optocouplers	200
Styles of Optoisolator.....	204
Optoisolator/Optocoupler Circuits	206
Example 9-1	207
Solution.....	208
Packaging of Optocouplers and Optoisolators	211
Optocoupler Application Circuits.....	212
Analog Multiplier Circuit	217
Notes	221

Chapter 10

Electronics Amplifiers for Electro-Optical Circuits	223
Properties of the "Ideal" Operational Amplifier.....	223
Differential Inputs	224
Circuit Analysis Using Ohm's Law and Kirchoff's Current Law	225
Example 10-1	227
Solution.....	228
Noninverting Followers	228
Operational Amplifier Power Sources	231
Practical Op-Amp Devices: Real-World Problems	232
DC Differential Amplifiers	235
Practical Circuit	238
Differential Amplifier Applications.....	241

Chapter 11

Electro-Optical Medical Instruments	243
Photocolorimetry	243
Photoplethysmograph: The Sensor You Can Build	249
Blood Oxygen Measurement by PPG.....	253
Summary	253
Notes	253

Chapter 12

Integrated Circuit Electro-Optical Sensors	255
Differential Light Measurement	262

Chapter 13

X-ray Sources and Radiation Detectors	263
The Nature of X-Rays	265
Example 13-1	267
Solution	267
Generating X-Rays	268
Geiger-Mueller Tubes	273
Photomultiplier Tubes	277
Scintillation Counters	278
PN Junction Diodes	279
Alpha Particle Detector	281

Chapter 14

Lasers	283
Laser Classification	284
Basic Concepts	284
Types of Lasers	289
Insulating Solid-State Lasers	289
Insulating Crystal Lasers	290
Excimer Lasers	291
Gas Lasers	291
Solid-State PN Junction Lasers	294
Driver Circuit for Solid-State Laser Diodes	297
Summary	300
Notes	301

Chapter 15

Fiber Optic Technology	303
Review of the Basics	307
Fiber Optics	310
Intermodal Dispersion	314
Graded Index Fibers	318
Losses in Fiber Optic Systems	320
Example 15-1	320
Example 15-2	321
Converting Between dB Notation and Gain Notation	322
Special dB Scales	324
Fiber Optic Communications Systems	329
Receiver Amplifier and Transmitter Driver Circuits	331
Notes	336

Chapter 16

Television Sensor Tubes	337
The Basic Television System	337
TV Camera Sensor Tubes	340

Chapter 17

More Optical Instruments	347
Flame Detectors	347
Photodensitometers	350
Example 17-1	353
Solution	353
Telescopes	354
Example 17-2	356
Simple Photographic Camera	358
Projectors	359
Compound Microscopes	360
Spectrophotometers	361
Ratiometric Instruments	362
Example 17-3	365

Chapter 18

Optical Sensor Resolution Improvement Techniques	367
Other Resolution Issues	373
Sensor Resolution Improvement Techniques (SRI)	375
Simulation Effort	381
Laboratory Model of the Two-Sensor Approach to SRI	381
Single-Sensor Method	382
Summary	383
References	384

Index	385
--------------------	------------



Preface

Electro-optics is the marriage of electronics and optics to form a wide variety of instruments, circuits, and devices with a large number of uses. For example, the "electric eye" used by the shopkeeper to alert her when customers arrive is an electrooptical device; the burglar alarm that alerts her when other-than-customers arrive after hours is also an electro-optical (E-O) device.

This book is about E-O *sensors*, i.e., those electronic transducers that convert light waves into a proportional voltage, current, or resistance. The coverage of the sensors will be wide enough to allow you to understand the physics behind the theory of operation of the device, and also the circuits used to make these sensors into useful devices. We will take a look at the photoelectric effect, photoconductivity, photovoltaics and PN junction photodiodes and phototransistors.

Also examined is the operation of lenses, mirrors, prisms and other optical elements. These discussions are keyed to a couple of chapters on light physics, which you will need to understand before studying E-O instruments.

Other devices including optoisolators, optical fibers, X-ray sensors, TV sensors and some additional optical instruments such as telescopes and scientific instruments are also discussed in detail. The circuits for using sensors in E-O instruments, and for interfacing them with computers, are also discussed in sufficient depth to allow you to apply them to practical situations.

The author wishes to acknowledge the assistance of editor Jim Rounds of SAMS, Steve Bigelow, and Bob Clark—who provided immense wisdom and advice.

Joseph J. Carr
P.O. Box 1099
Falls Church, VA 22041
E-mail: carrjj@aol.com

\$29.95

Electro-optics is the marriage of electronics and optics to form a wide variety of instruments, circuits, and devices with a large number of uses. The "electric eye" used by the shopkeeper to alert when customers arrive is an electro-optical device. Other devices include industrial production machinery, scientific and medical instruments, television cameras, and many others.

Electronic Circuit Guidebook, Volume 4: Electro-Optics is mostly about E-O sensors — those electronic transducers that convert light waves into a proportional voltage, current, or resistance. The coverage of the sensors is wide enough to allow you to understand the physics behind the theory of operation of the device, and also the circuits used to make these sensors into useful devices. This book examines the photoelectric effect, photoconductivity, photovoltaics, and PN junction photodiodes and phototransistors. Also examined is the operation of lenses, mirrors, prisms, and other optical elements keyed to light physics.

After discussing the basic sensors and optical elements, *Electronic Circuit Guidebook, Volume 4: Electro-Optics* examines other devices including optoisolators, optical fibers, X-ray sensors, TV sensors, and some additional optical instruments such as telescopes and scientific instruments. The circuits for using sensors in E-O instruments, and for interfacing them with computers, are also discussed in sufficient depth to allow you to apply them to practical situations. *Electronic Circuit Guidebook, Volume 4: Electro-Optics* is intended to teach the physics and operation of E-O devices, then proceed to circuits and methods for actual application of the devices in real situations.

PROMPT
PUBLICATIONS

A Division of
Howard W. Sams & Company
A Bell Atlantic Company
Indianapolis, IN

ISBN 0-7906-1132-5

